

TEMPERATURE GRADIENTS IN CZE

223

TABLE I

BUFFER TEMPERATURES AT THE CENTER AND AT THE WALL OF THE CAPILLARY

Parameters used: $L = 1$ m; $R_2 = 1.725 \times 10^{-4}$ m; $R_c = 1.875 \times 10^{-4}$ m; $T_s = 298$ K; $h = 10\,000$ W/m²K; $k_1 = 0.605$ W/mK; $k_2 = 1.5$ W/mK; $k_c = 0.155$ W/mK; $\alpha = 7.75$.

Power (W)	Eqn. 8			Parabolic		
	Center (K)	Wall (K)	ΔT (K)	Center (K)	Wall (K)	ΔT (K)
<i>Internal diameter = 50 μm</i>						
2	299.214	298.951	0.263	299.214	298.951	0.263
3	299.722	299.326	0.396	299.721	299.326	0.395
5	300.738	300.077	0.661	300.735	300.077	0.658
<i>Internal diameter = 100 μm</i>						
2	299.067	298.804	0.263	299.067	298.804	0.263
3	299.501	299.106	0.395	299.500	299.106	0.394
5	300.370	299.709	0.661	300.367	299.709	0.658

found from the two methods of calculation. Shown in Table I are results for several capillary internal radii and power inputs. The results in Table I have several important implications: (a) typical CZE systems exhibit small temperature drops between the center and the wall—under the usual operating conditions, temperature effects are minimal²; (b) within the limits of the power input shown in the table, the temperature difference between the center and the inner wall of the capillary is independent of the inner radius. However, the actual temperatures are a function of the internal radius, showing a decrease with an increase in the diameter; (c) the temperatures calculated using eqn. 8 are identical, for all practical purposes, to those calculated from eqn. 12 over the whole cross section of the capillary. Fig. 1 shows the temperature profile within the capillary. The line depicting the temperature behavior is actually the superposition of two lines, one calculated using eqn. 8 and the other calculated using the parabolic profile, eqn. 12.

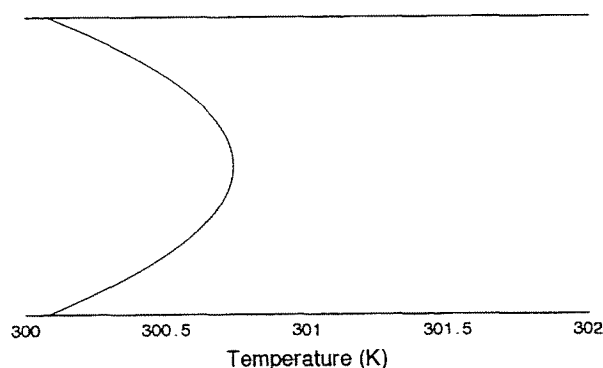


Fig. 1. Temperature profile as calculated from eqn. 8. Parabolic equation yields identical profile. Parameters used in the calculations are identical to those in Table I. Input power, 5 W; radius of capillary, 25 μ m.

TABLE II

BUFFER TEMPERATURE AT THE CENTER AND AT THE WALL AT HIGH INPUT POWERS

Parameters used: $L = 1$ m; $R_2 = 1.725 \times 10^{-4}$ m; $R_c = 1.875 \times 10^{-4}$ m; $T_a = 298$ K; $h = 10000$ W/m²K; $k_1 = 0.605$ W/mK; $k_2 = 1.5$ W/mK; $k_c = 0.155$ W/mK; $\alpha = 7.75$; internal diameter = 50 μ m.

Power (W)	Eqn. 8			Parabolic		
	Center (K)	Wall (K)	ΔT (K)	Center (K)	Wall (K)	ΔT (K)
10	303.280	301.954	1.326	303.270	301.954	1.315
15	305.826	303.832	1.995	305.805	303.832	1.973
25	310.930	307.586	3.344	310.874	307.586	3.288

Table I describes the results for a capillary whose overall outer diameter is 375 μ m. The conclusions drawn from the table are valid even if the capillary radius is changed, provided that the power input is the same. Eqn. 8 and the parabolic profile will yield similar results as long as the power input is relatively small. When the power is increased, the discrepancy between the two temperature profiles increases. Table II shows the results of the calculation for power inputs of 10, 15 and 25 W. If the CZE system is thermostated, such power inputs can be tolerated, as evidenced from the relatively low predicted temperatures. We see from Table II that as the power increases, eqn. 8 predicts a greater temperature difference between the center and the inner wall of the capillary. Both, eqns. 8 and 12 give a similar wall temperature. However, eqn. 8 calculates a higher center temperature than the parabolic equation. Fig. 2 shows the temperature profile as determined by both approaches. From Fig. 2 we can see that the greatest difference between eqn. 8 and the parabolic equation occurs in the center of the capillary. The difference between the two profiles is small even at very high power input values, which are not used in the conventional practice of CZE (e.g., 0.06 degree difference at a power input of 25 W). At such high input powers, the temperature difference between center and wall is rather high (above 3 degrees) so that the contribution to the plate height is prohibitively high².

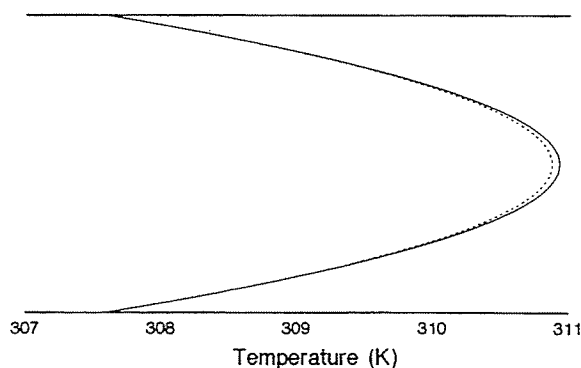


Fig. 2. Temperature profiles as calculated from eqn. 8 (—) and from the parabolic equation (---). Parameters used in the calculations are identical to those in Table II. Input power, 25 W; radius of capillary, 25 μ m.

TEMPERATURE GRADIENTS IN CZE

225

With relatively wide tubes (several mm in diameter), the resulting current is quite high at voltages which yield reasonable analysis times. In such cases, the power dissipated in the tube is very high, and eqn. 8 will be more accurate than eqn. 12 in predicting the temperature profile. However, the use of very wide tubes for CZE is not recommended since the temperature difference between center-to-wall will be much too large to obtain efficient separations.

CONCLUSIONS

Under the normal operating conditions, the nearly identical behaviors of eqns. 8 and 12, justify the use of parabolic temperature profiles in determining the effect of temperature on the efficiencies of CZE separations².

SYMBOLS

- A Integration constant
- G heat generation rate (W/m^3)
- G_0 heat generation in the absence of temperature dependence of the buffer (W/m^3)
- h heat transfer coefficient ($\text{W/m}^2\text{K}$)
- J_0 Bessel function of zero order and first kind
- J_1 Bessel function of first order and first kind
- k_1 thermal conductivity of the buffer (W/mK)
- k_2 thermal conductivity of the capillary wall (W/mK)
- k_c thermal conductivity of the polyimide coating (W/mK)
- L capillary length (m)
- R_1 inner radius of the capillary (m)
- R_2 outer radius of the quartz wall (m)
- R_c outer radius of the capillary; glass and polyimide (m)
- S reduced coefficient of heat generation (see eqn. 4)
- T_1 temperature at the inside wall of the capillary (K)
- T_s temperature of the capillary surrounding (K)
- U overall heat transfer coefficient ($\text{W/m}^2\text{K}$)
- y_1 dimensionless radial position r/R_1
- α coefficient of electrical conductivity of the buffer (dimensionless)
- β $(\alpha S)^{1/2}$
- γ reduced heat transfer coefficient (see eqn. 6)
- θ reduced temperature (see eqn. 4)

REFERENCES

- 1 J. W. Jorgenson and K. D. Lukacs, *Science (Washington, D.C.)*, 222 (1983) 266-272.
- 2 E. Grushka, R. M. McCormick and J. J. Kirkland, *Anal. Chem.*, 61 (1989) 241-246.
- 3 M. Coxon and M. J. Binder, *J. Chromatogr.*, 101 (1974) 1-16.
- 4 J. F. Brown and J. O. N. Hinckley, *J. Chromatogr.*, 109 (1975) 218-224.

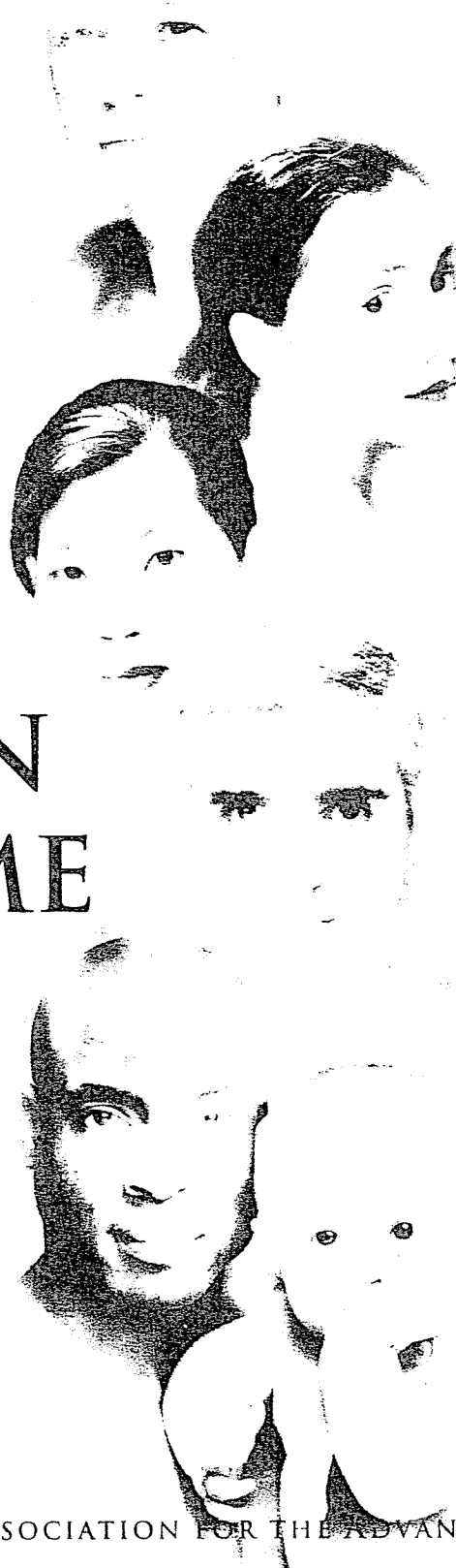
TAB 5

16 February 2001

Science

Vol. 291 No. 5507
Pages 1145-1434 \$9

THE HUMAN GENOME



A 41



AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Science THE HUM

Volume 291 16 February 2001 Number 5507

- | | |
|--|--|
| 1151 SCIENCE ONLINE | 1159 EDITORS' CHOICE |
| 1153 EDITORIAL
B. R. Jasny and D. Kennedy
<i>The Human Genome</i> | 1163 NETWATCH |
| 1155 THIS WEEK IN SCIENCE | 1166 CONTACT SCIENCE |
| | 1363 TECH.SIGHT/NEW PRODUCTS
Immunocytochemistry |

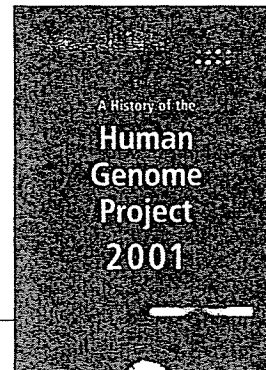


1177

The genome revealed

NEWS

- 1177 **The Human Genome**
- 1180 **Comparison Shopping**
- 1181 **Watching Genes Build a Body**
- 1182 **Controversial From the Start**
Objection #1: Big Biology Is Bad Biology
Objection #2: Why Sequence the Junk?
Objection #3: Impossible to Do
- 1183 **Finding the Talismans That Protect Against Infection**
- 1185 **Nailing Down Cancer Culprits**
- 1187 **A Parakeet Genome Project?**
- 1188 **Brain Calls Dibs on Many Genes**



1195

A pullout genome timeline

- 1189 **Sharing the Glory, Not the Credit**
Celera and *Science* Spell Out Data Access Provisions
Bermuda Rules: Community Spirit, With Teeth
- 1193 **Genomania Meets the Bottom Line**
Will a Smaller Genome Complicate the Patent Chase?
Can Data Banks Tally Profits?
- 1195 **Timeline: A History of the Human Genome Project**
In Their Own Words
A Genome Glossary
- 1204 **What's Next for the Genome Centers?**
- 1207 **Hunting for Collaborators of Killer Toxins**

SCIENCE'S COMPASS

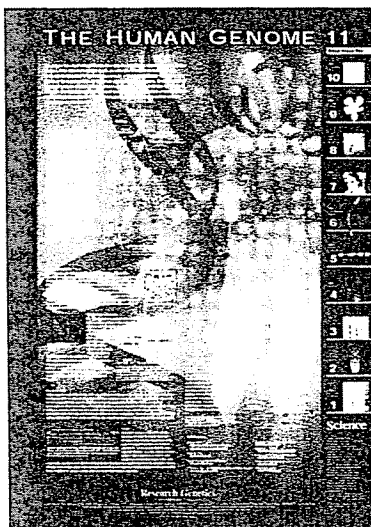
FUTURE DIRECTIONS

- 1219 **GENOMICS AND SOCIETY: The Human Genome and Our View of Ourselves**
S. Pääbo
- 1221 **PROTEOMICS: Proteomics in Genomeland**
S. Fields
- 1224 **GENOMICS AND MEDICINE: Dissecting Human Disease in the Postgenomic Era**
L. Peltonen and V. A. McKusick
- 1232 **GENOMICS AND BEHAVIOR: Toward Behavioral Genomics**
P. McGuffin, B. Riley, R. Plomin
- 1249 **POLICY ISSUES: Political Issues in the Genome Era**
J. M. Jeffords and T. Daschle
- 1251 **SEQUENCE INTERPRETATION: Functional Annotation of Mouse Genome Sequences**
The International Mouse Mutagenesis Consortium
- 1255 **GENE NUMBER: What If There Are Only 30,000 Human Genes?**
J.-M. Claverie
- 1257 **SEQUENCE INTERPRETATION: Making Sense of the Sequence**
D. J. Galas

- 1260 **COMPUTATIONAL BIOLOGY: Bioinformatics—Trying to Swim in a Sea of Data**
D. S. Roos

BOOK REVIEWS

- 1263 **MOLECULAR BIOLOGY: *Who Wrote the Book of Life? A History of the Genetic Code***
L. E. Kay, reviewed by R. C. Lewontin
- 1264 **GENETICS: *The Century of the Gene***
E. F. Keller, reviewed by S. B. Carroll
- 1265 **GENOMICS: *Cracking the Genome Inside the Race to Unlock Human DNA***
K. Davies, reviewed by S. Brenner

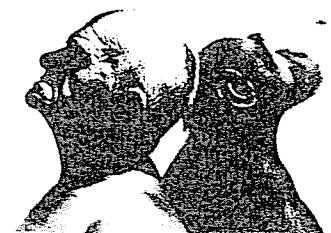


1233

A pullout introduction to the human genome effort

1219

Understanding ourselves



AN GENOME



RESEARCH

ANALYSIS OF GENOMIC INFORMATION

- 1279 Apoptotic Molecular Machinery: Vastly Increased Complexity in Vertebrates Revealed by Genome Comparisons**
L. Aravind, V. M. Dixit, E. V. Koonin

- 1284 Human DNA Repair Genes** R. D. Wood, M. Mitchell, J. Sgouros, T. Lindahl

- 1289 The Human Transcriptome Map: Clustering of Highly Expressed Genes in Chromosomal Domains** H. Caron, B. van Schaik, M. van der Mee, F. Baas, G. Riggins, P. van Sluis, M.-C. Hermus, R. van Asperen, K. Boon, P. A. Voûte, S. Heisterkamp, A. van Kampen, R. Versteeg

- 1293 Birth of Two Chimeric Genes in the *Hominidae* Lineage** A. Courseaux and J.-L. Nahon

- 1298 A High-Resolution Radiation Hybrid Map of the Human Genome Draft Sequence**
M. Olivier, A. Aggarwal, J. Allen, A. A. Almendras, E. S. Bajorek, E. M. Beasley, S. D. Brady, J. M. Bushard, V. I. Bustos, A. Chu, T. R. Chung, A. De Witte, M. E. Denys, R. Dominguez, N. Y. Fang, B. D. Foster, R. W. Freudenberg, D. Hadley, L. R. Hamilton, T. J. Jeffrey, L. Kelly, L. Lazzeroni, M. R. Levy, S. C. Lewis, X. Liu, F. J. Lopez, B. Louie, J. P. Marquis, R. A. Martinez, M. K. Matsuura, N. S. Misherghi, J. A. Norton, A. Olshen, S. M. Perkins, A. J. Perou, C. Piercy, M. Piercy, F. Qin, T. Reif, K. Sheppard, V. Shokoohi, G. A. Smick, W.-L. Sun, E. A. Stewart, J. F. Tejada, N. M. Tran, T. Trejo, N. T. Vo, S. C. M. Yan, D. L. Zierten, S. Zhao, R. Sachidanandam, B. J. Trask, R. M. Myers, D. R. Cox

THE HUMAN GENOME

- 1304 The Sequence of the Human Genome**
J. C. Venter, M. D. Adams, E. W. Myers, P. W. Li, R. J. Mural, G. G. Sutton, H. O. Smith, M. Yandell, C. A. Evans, R. A. Holt, J. D. Gocayne, P. Amanatides, R. M. Ballew, D. H. Huson, J. R. Wortman, Q. Zhang, C. D. Kodira, X. H. Zheng, L. Chen, M. Skupski, G. Subramanian, P. D. Thomas, J. Zhang, G. L. G. Miklos, C. Nelson, S. Broder, A. G. Clark, J. Nadeau, V. A. McKusick, N. Zinder, A. J. Levine, R. J. Roberts, M. Simon, C. Slayman, M. Hunkapiller, R. Bolanos, A. Delcher, I. Dew, D. Fasulo, M. Flanigan, L. Florea, A. Halpern, S. Hannenhalli, S. Kravitz, S. Levy, C. Mobarry, K. Reinert, K. Remington, J. Abu-Threideh, E. Beasley, K. Biddick, V. Bonazzi, R. Brandon, M. Cargill, I. Chandramouliswaran,

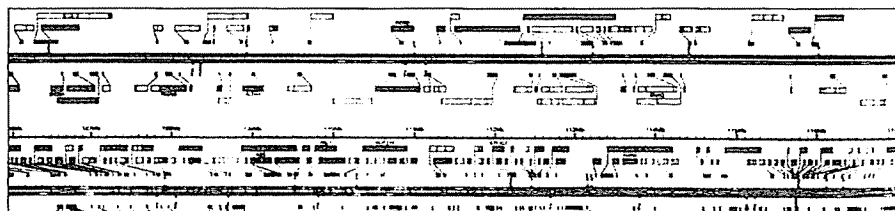
R. Charlab, K. Chaturvedi, Z. Deng, V. Di Francesco, P. Dunn, K. Eilbeck, C. Evangelista, A. E. Gabrielian, W. Gan, W. Ge, F. Gong, Z. Gu, P. Guan, T. J. Heiman, M. E. Higgins, R.-R. Ji, Z. Ke, K. A. Ketchum, Z. Lai, Y. Lei, Z. Li, J. Li, Y. Liang, X. Lin, F. Lu, G. V. Merkulov, N. Milshina, H. M. Moore, A. K. Naik, V. A. Narayan, B. Neelam, D. Nusskern, D. B. Rusch, S. Salzberg, W. Shao, B. Shue, J. Sun, Z. Y. Wang, A. Wang, X. Wang, J. Wang, M.-H. Wei, R. Wides, C. Xiao, C. Yan, A. Yao, J. Ye, M. Zhan, W. Zhang, H. Zhang, Q. Zhao, L. Zheng, F. Zhong, W. Zhong, S. C. Zhu, S. Zhao, D. Gilbert, S. Baumhueter, G. Spier, C. Carter, A. Cravchik, T. Woodage, F. Ali, H. An, A. Awe, D. Baldwin, H. Baden, M. Barnstead, I. Barrow, K. Beeson, D. Busam, A. Carver, A. Center, M. L. Cheng, L. Curry, S. Danaher, L. Davenport, R. Desilets, S. Dietz, K. Dodson, L. Doup, S. Ferreira, N. Garg, A. Gluecksmann, B. Hart, J. Haynes, C. Haynes, C. Heiner, S. Hladun, D. Hostin, J. Houck, T. Howland, C. Ibegwam, J. Johnson, F. Kalush, L. Kline, S. Koduru, A. Love, F. Mann, D. May, S. McCawley, T. McIntosh, I. McMullen, M. Moy, L. Moy, B. Murphy, K. Nelson, C. Pfannkoch, E. Pratts, V. Puri, H. Qureshi, M. Reardon, R. Rodriguez, Y.-H. Rogers, D. Romblad, B. Ruhfel, R. Scott, C. Sitter, M. Smallwood, E. Stewart, R. Strong, E. Suh, R. Thomas, N. N. Tint, S. Tse, C. Vech, G. Wang, J. Wetter, S. Williams, M. Williams, S. Windsor, E. Winn-Deen, K. Wolfe, J. Zaveri, K. Zaveri, J. F. Abril, R. Guigó, M. J. Campbell, K. V. Sjolander, B. Karlak, A. Kejariwal, H. Mi, B. Lazareva, T. Hatton, A. Narechania, K. Diemer, A. Muruganujan, N. Guo, S. Sato, V. Bafna, S. Istrail, R. Lippert, R. Schwartz, B. Walenz, S. Yooseph, D. Allen, A. Basu, J. Baxendale, L. Blick, M. Carninha, J. Carnes-Stine, P. Caulk, Y.-H. Chiang, M. Coyne, C. Dahlke, A. D. Mays, M. Dombroski, M. Donnelly, D. Ely, S. Esparham, C. Fosler, H. Gire, S. Glanowski, K. Glasser, A. Glodek, M. Gorokhov, K. Graham, B. Gropman, M. Harris, J. Heil, S. Henderson, J. Hoover, D. Jennings, C. Jordan, J. Jordan, J. Kasha, L. Kagan, C. Kraft, A. Levitsky, M. Lewis, X. Liu, J. Lopez, D. Ma, W. Majoros, J. McDaniel, S. Murphy, M. Newman, T. Nguyen, N. Nguyen, M. Nodell, S. Pan, J. Peck, M. Peterson, W. Rowe, R. Sanders, J. Scott, M. Simpson, T. Smith, A. Sprague, T. Stockwell, R. Turner, E. Venter, M. Wang, M. Wen, D. Wu, M. Wu, A. Xia, A. Zandieh, X. Zhu

COVER

The face of the human genome. A scientific milestone of enormous proportions, the sequencing of the human genome will impact all of us in diverse ways—from our views of ourselves as human beings to new paradigms in medicine. This entire issue is devoted to the scientific announcement of the sequencing of the human genome, initial analyses of the genome and genomic data, as well as Viewpoints and News features discussing the implications of the results and paths for the future. [Image: Ann Elliott Cutting]

1304

Annotation of the Celera Human Genome Assembly (Fig. 1 of Venter *et al.*, included as a separate wall chart)



AMERICAN
ASSOCIATION FOR THE
ADVANCEMENT OF
SCIENCE

SCIENCE (ISSN 0036-8075) is published weekly on Friday, except the last week in December, by the American Association for the Advancement of Science, 1200 New York Avenue, NW, Washington, DC 20005. Periodicals Mail postage (publication No. 484460), and postage for Ride Along enclosure, is paid at Washington, DC, and additional mailing offices. Copyright © 2001 by the American Association for the Advancement of Science. The title SCIENCE is a registered trademark of the AAAS. Domestic individual membership and subscription (\$1 issues): \$115 (\$64 allocated to subscription). Domestic institutional subscription (\$1 issues): \$370; Foreign postage extra: Mexico, Caribbean (surface mail) \$55; other countries (air assist delivery) \$87. First class, airmail, student, and emeritus rates on request. Canadian rates with GST available upon request. GST #1254 88122. Publications Mail Agreement Number 1069624. Printed in the U.S.A.

Change of address: allow 4 weeks, giving old and new addresses and 8-digit account number. Postmaster: Send change of address to Science, P.O. Box 1811, Danbury, CT 06813-1811. Single copy sales: \$9.00 per issue prepaid includes surface postage; bulk rates on request. Authorization to photocopy material for internal or personal use under circumstances not falling within the fair use provisions of the Copyright Act is granted by AAAS to libraries and other users registered with the Copyright Clearance Center (CCC) Transactional Reporting Service, provided that \$9.00 per article is paid directly to CCC, 222 Rosewood Drive, Danvers, MA 01923. The identification code for Science is 0036-8075/83 \$9.00. Science is indexed in the Reader's Guide to Periodical Literature and in several specialized indexes.

Scienceonline

www.scienceonline.org

CONTENT HIGHLIGHTS AS OF 16 FEBRUARY 2001

science magazine www.sciencemag.org

SCIENCE EXPRESS www.sciencexpress.org

X-ray Pulses Approaching the Attosecond Frontier M. Drescher, M. Hentschel, R. Kienberger, G. Tempea, C. Spielmann, G. A. Reider, P. B. Corkum, F. Krausz

PERSPECTIVE: Toward Attosecond Pulses D. T. Reid

The generation of x-ray pulses shorter than the several-femtosecond optical pulses used to create them pave the way to the attosecond time regime.

High Macromolecular Synthesis with Low Metabolic Cost in Antarctic Sea Urchin Embryos A. G. Marsh, R. E. Maxson Jr., D. T. Manahan

An Antarctic sea urchin compensates for the disadvantages of its low-temperature environment through enhanced rates of protein and RNA synthesis—while still maintaining a low metabolic rate.

An RNA Ligase Essential for RNA Editing and Survival of the Bloodstream Form of *Trypanosoma brucei* A. Schnauffer, A. K. Panigrahi, B. Panicucci, R. P. Igo Jr., R. Salavati, K. Stuart
Knockout of an RNA ligase shown to be involved in RNA editing in trypanosomes kills the bloodstream form of the parasite and saves the host mice from death.

SPECIAL FEATURES

Science Functional Genomics www.sciencegenomics.org
We launch a new section on the human genome, including links to articles, Web resources, and online glossaries, as well as some classic *Science* papers and news coverage.

science's stke

www.stke.org

Review: The Ethylene Pathway—A Paradigm for Plant Hormone Signaling and Interaction J. M. Alonso and J. R. Ecker

Ethylene signaling in plants shows complex cross talk with multiple signaling pathways.

Q&A: Genomes—A Platform for Signal Transduction Research

An open forum moderated by the STKE editors.

science's next wave

www.nextwave.org

Global: Bioinformatics Training and Careers Next Wave Staff

Want to know what the genome can do for your career? Check out our recent special feature on bioinformatics (<http://nextwave.sciencemag.org/cgi/content/full/2000/08/23/1>).

Canada: Evaluating the Scientist in You, Part 1 D. Treen

An exploration of the differences between large and small biotech firms, and the employee characteristics that fit best with each.

UK: Going Global 2—Making Contact P. H. Dee

Practical advice on piquing the interest of potential collaborators, from our "Yours Transferably" columnist.

Germany: Going It Alone J. Wolf

Some German funding organizations have programs that assist single parents wishing to pursue postdoctoral studies abroad. Read about one of them.

GrantsNet
www.grantsnet.org
RESEARCH FUNDING DATABASE

NeuroAIDS
www.sciencemag.org/NAIDS
EXPERIMENTAL WEB SITE

ONLINE STAFF

SCIENCE NOW EDITORS Laura Helmuth, Martin Enserink, Erik Stokstad

SCIENCE'S NEXT WAVE EDITORIAL: MANAGING EDITOR Crispin Taylor; EDITORS Robert Metzke (Germany), Kirstie Urquhart (UK); CONTRIBUTING EDITORS Lesley McCarney (Canada), Mark Sincell; PROJECT MANAGER Emily Klotz; WRITERS Katie Cottingham, Mona Mort; MARKETING: MARKETING MANAGERS Karen Horting (US and Canada), Hazel Crocker (Europe); PROGRAM DIRECTOR Lisa Kozlowski; MARKETING ASSOCIATE Joey D'Adamo

SCIENCE'S STKE EDITOR Bryan Ray; ASSOCIATE EDITORS Lisa Chong, Nancy Gough, John Nelson

ELECTRONIC MEDIA MANAGER David Gillikin; INTERNET PRODUCTION MANAGER Betsy Harman; ASSISTANT PRODUCTION MANAGER Wendy Stengel; SENIOR PRODUCTION ASSOCIATE Lisa Stanford; ASSOCIATES Carla Cathey, Mark Croatti, Robert Owens, Louis Williams

Daily coverage of science and science policy by *Science's* news team

sciencenow

www.sciencenow.org

NOW!

SCIENCECAREERS.ORG

Resumes
Science

Database
Science

ADDITIONAL RESOURCE

ADDITIONAL RESOURCE

ADDITIONAL RESOURCE

FOCUS ON CAREERS

omei
Science

Science
omel

LAB TECHNOLOGY TRENDS

Technology
Research

Ca

